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FOSSILS AND FOSSILIZATION.

BY L. P. GRATACAP.

II.

(Continued from page 912).

The replacing and mineralizing influence of surface waters may preserve bones which would otherwise quickly disappear. At Big Bone Lick in Kentucky the great numbers of bones of the buffalo are found according to Prof. Shaler "near the present position of the springs and never at any depth beneath the surface." These bones are in some places "massed to the depth of two feet or more, as close as the stones of a pavement, and so beaten down by the succeeding herds as to make it difficult to lift them from their bed." The attraction of this locality for the herds of wild animals spread through the forests of Kentucky in pliocene and recent times, arose from the saline encrustations made by the natural brines which spring to the surface at this point. There is an ossuary of their remains, the mastodon and elephant bones being upon the higher levels and the buffalo skeletons placed more within the swampy basin, which has itself undergone denudation since the advent of the great proboscideans. These bones are impregnated with salt¹ and have become partially mineralized, while the salt solution itself neutralizes any vegetable acids arising from the decomposition of the reeds which, according to Mr. Cooper, accompany the bones. Yet the falling into swamps or bogs of the great mammals and their gradual submersion and burial in the deeper layers of the tenacious and yielding mixture, has been a means of preserving their remains, especially, as besides their partial immunity from the action of organic acids, their great bones have formed, from their formidable size and texture, an irreducible nucleus. But

¹ The preservation of the bones of the *Megalonyx* in the Big Bone cave in Tennessee, may be partially ascribed to the presence of large quantities of saltpeter earth.

when we reinvest this continent with herds of wild animals, gregarious in habit, and probably reaching a great numerical aggregate, it seems at first singular that their entire skeletons should be so infrequent. The Mastodon, the Elephant, the Musk Ox,² the Caribou Moose³, and the Reindeer, Horse, Buffalo and Mylodon have been distributed in pliocene and recent times as far south as Kentucky, yet except under peculiar circumstances of sepulture, their remains have disappeared. The conclusion is irresistible that the placement of the bones of vertebrates upon the surface of the ground is unfavorable to fossilization, that they must be covered in by deposits, and while thus held together become hermetically sealed against the accidents of surface conditions and the solution by carbonated and acid waters. The rhinoceros and elephant which were disappearing from Sumatra at the time of Mr. Wallace's visit had, after so recent a withdrawal, left few traces more than crania, tusks and teeth. Prof. Nordenskiöld speaking of the polar regions pertinently remarks, "the Polar bear and the reindeer are found there in hundreds, the seal, walrus and white whale in thousands, and birds in millions. These animals must die a 'natural' death in untold numbers. What becomes of their bodies? Of this we have for the present no idea."

The isolated death of individuals from packs of wild animals or the death of those less social in instinct, does not, under most circumstances, insure preservation. When some spot chosen for its proximity to water, or because of its fertility and nourishing vegetation, becomes a rendezvous of groups of animals, the herbivores being followed by the beasts of prey, and the region thus frequented is so situated as to receive the

² The Musk Ox, *Ovibos cavifrons* Leidy, was found in Loess of Iowa at Council Bluffs, twelve feet below the surface; also at Ft. Gibson, I. T., St. Louis, New Madrid, Mo., Ohio, Big Bone Lick, Ky. These specimens afforded little else than the head, separated vertebrae and leg bones.

³ Bones of the fossil elk or moose have been found at Big Bone Lick, Kentucky, but it was reserved for Prof. W. B. Scott, of Princeton College, N. J., to obtain the magnificent example of *Cervalces americanus* Harlan now exhibited in the cabinet of that institution. This almost complete skeleton of a very large extinct elk or moose was discovered in a *shell marl deposit under a bog* at Mt. Hermon, N. J. (See Proc. Acad. Nat. Sci. Phila., 1885, p. 181).

drainage of the higher land, a combination of conditions is provided by which a varied fauna may secure an approximately complete representation in fossils. Such localities as those described by Captain Johnston in his Nyassaland are suggested. He says: "At the close of the dry season when the tall grass has been burnt down and there is little or no cover for the game to hide in, it is really a remarkable spectacle as seen from the deck of a steamer, to watch the great herds of big animals wandering over these savannahs in search of the young verdure springing up amid the charred stubble of the old grass.⁴ With an opera glass you may distinguish water-buck, gnu, buffalo, eland, pallah, reed-buck and zebra, and occasionally some dark blue-gray blobs, much larger than the other specks and forms which are in their vicinity, turn out to be elephants." Again he says "game in the shape of antelopes and buffaloes was evidently abundant, and no doubt was attracted to the vicinity of this brackish pool by the flakes of salt which remained on the soil when the water had evaporated; and the game in its turn was followed by hyenas, lions and vultures."⁵

In geological time such localities would have afforded a rich commixture of fossil remains if the circumstances favorable for the deposition of a protecting stratum of earth existed. Yet in all instances the social relations of the animals have an importance, and those social relations are somewhat modified by the topography of the country they inhabit. The wide plains of south-eastern or subcentral Africa, with an unchecked communication for miles, numerous rivers and rich vegetation,

⁴ Such scenes described by Capt. Johnston are closely imitated in the picture, drawn by W. Boyd Dawkins, of the Bristol Channel in pliocene times, when it was a fertile plain "supporting herds of reindeer, horses and bisons, many elephants and rhinoceroses, and now and then being traversed by a stray hippopotamus, which would afford abundant prey to the lions, bears and hyenas inhabiting all the accessible caves, as well as to their enemy and destroyer, man." See also Dr. E. Holub's "Seven Years in S. Africa," Vol. I, p. 267.

⁵ See also East Africa and its Big Game by Sir John C. Willoughby, wherein he describes the open plain with buffalo, zebra, hartebeest, eland, rhinoceros, ostrich, Grant's antelope, steinbock and wart-hog scattered over it, and in another place where he saw "lions, rhinoceros, lesser kudu, wild dogs, hyenas, cheetah, water-buck and zebra, the total seen amounting to nineteen varieties."

permit a most heterogeneous assemblage of animals, whereas a disturbed and mountainous country divided into lofty plateaux, low savannahs and barricaded valleys would separate and isolate related groups, and from a low zoic maxima,⁶ in consequence of its irregularity and limited geographical scope, afford a meagre and less diversified fauna, and actually fewer fossils. The successful fossilization of the bones of terrestrial vertebrates can best be secured by their rapid burial within impervious beds of enveloping material wherein they undergo a slow process of partial or complete petrification. Nordenskiöld in his *Voyage of the Vega* discovered a very extensive deposit of whale bones in a sand dune upon a beach of Siberia in the Chuckchi country. These apparently had fallen to the bottom of a sea and were entombed by new layers and beds of sand. They were thus subfossil and possessed an immense age. Where they had become exposed by the violence of the waves they were decaying, but where buried in the sand the well preserved bones of these cetaceans were found in innumerable quantities.

The dispersal of bones in the ocean seems as unfavorable to their preservation as exposure on the surface of the earth or in the vegetable acids of its superficial covering. It is notorious that the dredging expeditions deputed to explore the depths of the oceans have seldom encountered the remains of vertebrate animals. The skeletons of whales, seals, porpoises and sharks have not been found commonly, though teeth brought up from these depths indicate the dissolution of the animals in the oceanic waters. So striking is this absence of osseous remains that Lyell remarks "there are regions at present, in the Indian and Pacific Oceans, coextensive in area with Europe and North America where we might dredge the bottom and draw up thousands of shells and corals without obtaining one bone of a land quadruped."⁷

⁶ See *AMER. NAT.*, Vol. XX, p. 1009.

⁷ "Some astonishment was created on board the 'Challenger' that the dredge after having dragged over miles and miles of the bottom of the sea, and up and down almost every oceanic basin, should never bring up any bones of fish or whale, or any remains of other large animals which inhabit the sea or whose bodies may have been carried down to the sea." *Thalassa*, J. J. Wild, p. 133.

The explanation of this fact has hardly advanced further than the theoretical stage. It may be attributed to the dissolving agency of carbonic anhydride in the lower strata of water, to the insidious action of the products of organic change, which Julien seems inclined to exaggerate, or to the more ordinary factors of animal consumption. Prof. Verrill and Mr. Sanderson Smith hold that the disappearance of bone in the ocean is due to its being attacked and eaten by crustacea.⁸ If this is true and solution has no practical bearing, as an agent in their disappearance, it seems likely that some maceration and softening produced by pressure and soakage reduce the bone to such a consistency as to render it more easily attacked by these animals, and incidentally render the bones themselves liable to separation and absorption by the sea waters. It is peculiar that while great numbers of shells are raised from the bottom of the ocean, the same areas seldom or never produce mammalian relics, the otoliths or ear bones of whales, and the teeth of sharks excepted. The skeletons of sharks and fishes might naturally undergo softening or become from their semicartilaginous nature the prey of smaller animals, but the hard parts of whales seem well calculated to resist attack. These larger animals upon their death may be dragged by submarine currents into the deeper parts of the ocean and there become subjected to a stronger chemical action than is observable at less depths. The theory of Mr. Murray as to the formation of coral reefs would make it appear that bottom waters contain more carbonic acid than those on the surface, but this Prof. Dittmar⁹ calls in question, thinking that solution is effected by the prolonged contact with the sea water itself. At any rate "the alkalinity of bottom waters was

⁸ It is a matter of some interest to learn that "remains of the Atlantic Walrus in a fossil state, have been found at various points along the Atlantic Coast from Maine to South Carolina, and in Europe as far south as England and France" (J. A. Allen). The most striking instance is that of a skull found on the sea beach at Long Branch, New Jersey, of which Dr. Leidy said it "has lost a portion of the cranium proper, and the exerted portion of one tusk, but otherwise, except being a little water worn, is in a good state of preservation."

⁹ The Physics and Chemistry of the voyage of H. M. S. Challenger, Vol. I, pt. 1, Composition of Ocean Water by Prof. W. Dittmar.

found to be distinctly greater than that of those from the surface, and this increase was exactly proportional to the larger quantity of lime present in the former," and upon this fact we might found a belief that bones disappeared through solution. At considerable depths pressure would greatly reinforce chemical action, and as carbonic anhydride is liquified under a pressure of something over 38 atmospheres, in the deeper basins of the ocean this reagent may exist as a liquid. In a French experiment, water, taken from a great depth of ocean, was under so high a tension from the enclosed gas, that upon release it spurted in a jet from the containing vessel.

The remains of terrestrial vertebrates represent most generally the submergence and death of the living animals themselves, and Lyell has well described the way. He says (Principles, (Vol. II, p. 542), "river inundations recur in most climates at very irregular intervals and expend their fury on those rich alluvial plains, where herds of herbivorous quadrupeds congregate together. These animals are often surprised, and, being unable to stem the current, are hurried along until they are drowned, when they sink at first immediately to the bottom. Here their bodies are drifted along, together with sediment, into lakes or seas, and may then be covered by a mass of mud, sand and pebbles thrown down upon them.

"Where the body is so buried in drift sand, or mud accumulated upon it, as never to rise again, the skeleton may be preserved entire; but if it comes again to the surface while in the process of putrefaction, the bones commonly fall piecemeal from the floating carcass, and may in that case be scattered at random over the bottom of the lake, estuary, or sea, so that a jaw may afterwards be found in one place, a rib in another, a humerus in a third—all included, perhaps, in a matrix of fine materials where there may be evidence of very slight transporting power in the current, or even of none, but simply of some chemical precipitate."

Entire skeletons of animals or their bones scattered over declivities or plains are not so likely to be gathered together and deposited in some spot, because, as we have seen, they become subject to decay and dissipation., and because it would

appear that any wide-spread catastrophes killing large numbers of a herd are rare, and in the case of individual deaths, the remains, if carried by freshets to some lower level, would seldom undergo the same vicissitudes and be buried at the same point. Yet the wholesale destruction of mammals in a state of nature may be considered a possibility, though improbable. Sir Samuel H. Baker speaks¹⁰ of cattle introduced at his camp at Fatiko, in Africa, who could not live there, "as the herbage was quite different to that to which they had been accustomed." They died so rapidly and in such numbers that in three months only three or four remained out of as many thousand. In the over stocked ranches of California, thousands of heads of sheep have been seen lying dead in vast heaps in ravines and valleys, as if nourishment had become exhausted by draught or by actual depletion of the available pasturage. Is not a similar mortality possible under natural conditions when, as in the case of the Fatiko cattle, animals have been driven by storms into localities incapable of their support, or when, as with the ranch sheep of California, an area previously put under severe strain for the support of its feral population, by an accident of weather or season fails entirely to furnish its occupants with food?

Wallace in his Malay Archipelago speaks of the destructive effects of drought upon animal life in the Arne Islands, where from an excessive scarcity of water, "sometimes hundreds of birds and other animals die." The effects of sudden and violent falls of hail and snow are noticed by Stansbury, who found on the shores of the Great Salt Lake, a large number of young pelicans killed by the severity of a hail storm. The possibility of numbers of animals becoming buried at once, may be illustrated in the condition of the banks of the River Vaal in South Africa, of which Dr. Holub says that "its banks almost to the very middle of the channel are so soft and slippery, that draught animals going to drink are liable to sink so deep into the mud that it is impossible to extricate them." The internecine strife of wild animals may itself result in the accidental death of numbers, as when the hunters

¹⁰ Ismailia, Sir S. H. Baker. p. 294.

—the carnivora—pursue their prey and drive them into lakes or rivers or, perhaps, force them over precipices. Dr. Hayden has observed similar occurrences, and in the same place where he records this observation corroborates the interesting suggestion of Lyell as to animals meeting their death by falling through thin ice. He says: "The wolves watch the deer, antelope and other feebler animals as they go down to the streams to drink, and all over the wide bottoms are the skeletons of these animals in a more or less perfect condition. It is not an uncommon occurrence for a band of wolves to attack an aged buffalo too old to offer a successful resistance. He must always betake himself to the river, where he is not unfrequently drowned, or is destroyed by the wolves on a sand bar or island. Annually thousands of buffaloes are drowned in attempting to cross the Missouri on the ice, as it is breaking up in the spring. Their bodies have been seen floating down the Missouri at Fort Union and Fort Clark by hundreds, and lodging on some of the islands or sand bars in the river. In the spring of 1858 several thousand bodies of buffaloes passed down the Kansas River below the mouth of Solomon's Fork and were carried into the Missouri."

Dr. Holub speaks of the devastation amongst oxen, elands, hartebeests, sheep, goats, wild pigs, etc., wrought by the attacks of hyenas in South Africa as "really frightful," and in pliocene times on our globe similar causes may have led to the collection of important groups of fossils. Even the instincts of animals may lead to their wholesale destruction. Mosely speaks of the migration of turtles at Ascension Islands saying, "the young turtles on leaving the egg go down to the sea and disappear, returning only when full grown to breed; this is the account given by the residents. If they do really leave the neighborhood of the island, there seems no possible means by which they can find their way back."

Although it is impossible that any of the fish beds, found as fossils, can, at least in paleozoic or mesozoic rocks, have been formed in the way instanced by Nordenskiöld as a cause of death amongst arctic fish, yet the circumstance is intrinsically interesting, and the the reflections it suggests as to the likeli-

hood of general destruction from other causes of the fish in geological strata, wherein they abound, make it a useful point of reference in this matter. Nordenskiöld says (Voyage of the *Vega*), "a large number of fish (*Gadus polaris*) were seen above the foot of a large block of ground ice, near which we lay to for some hours. Next day we saw near one of the islands, where the water was very clear, the sea-bottom bestrewed with innumerable fish of the same species. They had probably perished from the same cause, which often kills fish in the river Obi in so great numbers that the water is infected, namely, from a large shoal of fish having been inclosed by ice in a small hole, where the water, when its surface has frozen, could no longer by absorption from the air replace the oxygen consumed, and where the fish have thus been literally drowned."

However accumulated, whether by the sudden death of large numbers of animals by floods and storms along the banks of streams or the margins of lakes, or whether from other natural causes animals perish in numbers and upon restricted areas, their bones are carried by water action into the depressions, sinks, crevices and basins of a country, and being there sealed up from decomposition or dispersion by the silt and gathering accretions of various mineral deposits above them, they become fossils. The caves in limestone districts receive a contribution of animal remains partially brought into them by surface water partially by the predatory instincts of carnivorous mammalia or birds. Prof. Hartt in his *Geology of Brazil* instances the interesting examples in the Sao Francisco basin wherein the numerous caverns, extending sometimes two thousand feet into the rock, furnish abundant remains both of long extinct mammalia as the *Glyptodon*, *Mastodon*, *Myodon*, *Megatherium*, *Chlamydotherium*, *Toxodon* and *Macrauchenia*, and innumerable remnants of the smaller living animals brought there by owls, whose bones mingle with those of other occupants, as bats and felidæ. These variously distributed in the different caves were mingled in a red clay earth more or less cemented and encrusted by a stalagmitic crust. Similarly fossil vertebrates have been entombed in the caves of England, France, Belgium, Spain,

Sicily, Germany, Russia and Australia. Many of these caves open by vertical fissures to the surface, and down these irregular holes and chimneys the bones have been washed, while in some cases as at Wirksworth, in Derbyshire, England, or at the *cave* in the limestone at Port Kennedy, Pa., described by C. M. Wheatley, animals may have plunged into them and died in their imprisonment. Once gathered in their final resting place the process of burial goes on, in many cases rapidly, and in others slowly, and, according to the completeness of their sepulture, the condition of the bone is more or less perfectly preserved. In river floods the animals or osseous debris borne forward in their waters are soon enveloped in the midst of the accompanying clay, sand, gravel and calcareous mud torn from the channel and banks of the stream. They sink to the bottom and are rapidly covered in by a rising blanket of deposition. In caves and hollow receptacles the infiltrating streams bring constant additions of mud, and by their erosive action upon the surrounding limestone which they dissolve, they redeposit carbonate of lime through the interstices of the granular accumulation or form a hard layer above it, upon which again later ossuaries may be made, and the cave floor offer a study of separate and successive periods.

Amongst the multitudinous details connected with the exploration of caves for the traces and evidence of prehistoric man, the following facts have some reference to the fossilization of terrestrial vertebrates. A cave at Gailenreuth, Germany, contains an enormous quantity of bones and teeth of animals formerly living in its vicinity, and according to Dr. Buckland, introduced by a stream which passed through this chain of caverns in its subterranean course to lower levels. In the cave of Kühloch, Germany, a black animal dust covers the whole floor to the depth of six feet, derived says the same authority "from comminuted and pulverized bone." This accumulation is attributed to the use of the cave by bears through centuries.¹¹ In the caves of North Wales near St.

¹¹ The habits of wild animals in resorting to caves is fully established by observation. The custom of the panthers to make lairs of natural caves is instanced by Prof. Baird, and Major Pinto speaks of a circular chamber in a limestone mountain in Western Africa as a "regular haunt of wild beasts, as one might

Asaph, the bones are in a similarly pulverulent state and produce clouds as they are disturbed. In a cave at Banwell in the Mendip Hills, England, thousands of bones of bison, horse and reindeer were taken out of a red silt which filled the cave to its roof. The entire deposit has been introduced by water through a vertical fissure which opened on the surface. In the Hyena Den, at Wookey Hole, "the organic remains were in all stages of decay, some crumbling to dust at the touch, while others were perfectly preserved and had lost very little of their gelatine." In an arm or section of this same cavern according to Dawkins, "most of the bones were as soft as wet mortar," an interesting statement which throws light upon the probable state of maceration which bones attain before disappearance by trituration or solution. The mineralization of the bones in the various caves, so patiently explored, presents striking differences. In some the bone seems reduced to the last stages of cohesion, while in others it has become filled with carbonate of lime or partially silicified, and attains a considerable gravity.

(*To be continued.*)

THE GEOGRAPHICAL DISTRIBUTION OF BATRACHIA AND REPTILIA IN NORTH AMERICA.

BY E. D. COPE.

(*Continued from page 902.*)

III. THE EASTERN SUBREGION.

The fauna of *Batrachia* and *Reptilia* of this subregion is characterized by what it lacks as much as by what it possesses. The number of species which occupy its entire extent exclude from the air which was perfectly saturated with the pungent smell of certain animals, as well as from the traces of a lion impressed on the impalpable powder which covered the ground, where we met with a few quills of the *Hystrix africana*."